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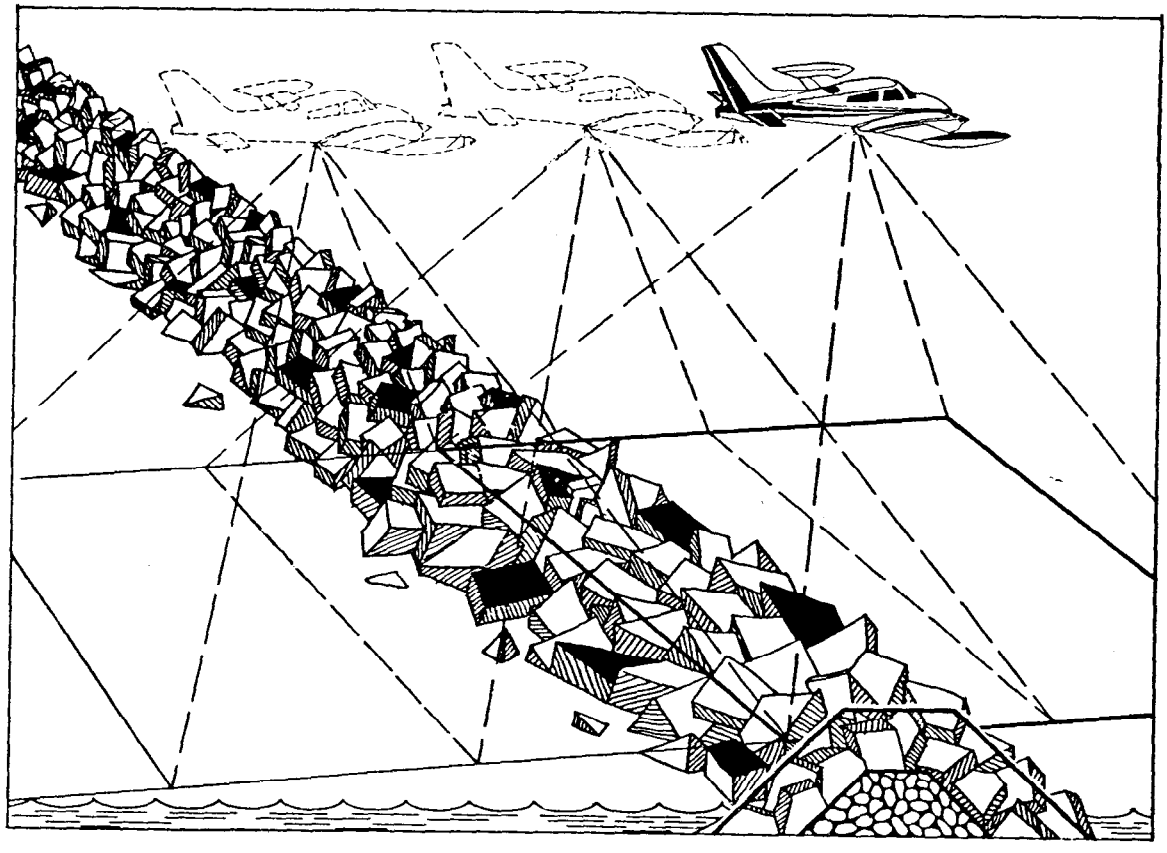
Coastal Engineering Technical Note

MONITORING RUBBLE-MOUND COASTAL STRUCTURES WITH PHOTOGRAMMETRY



INTRODUCTION: Monitoring coastal projects usually involves repeated surveys of coastal structures and/or beach profiles. When a coastal structure such as a jetty is protected with concrete armor units or quarrystone, monitoring the movement of individual units may be difficult, if not impossible, by conventional survey methods. Photogrammetric techniques, however, can be used to get precise measurements from properly acquired aerial photographs. When the structure is photographed at low tide, an accurate, permanent record of all visible armor units can be obtained, which record can then be analyzed or

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"surveyed" with stereoscopic photogrammetric compilation instruments to reveal any movement of the units.

PROCEDURE: The following steps are important to a successful monitoring program using photogrammetry.

Step 1: Selection of aerial photography company. The measurements obtained from an aerial photograph depend on the precision of the equipment and instruments used and the skill of the photogrammetrist and pilot. Calibration certificates of all available aerial mapping cameras should be reviewed so that a camera with acceptable capabilities is selected; measurements within ±0.3 ft should be expected for this type of project. In order to maximize repeatability of results, the same camera, aerial film, airplane, pilot, photogrammetric instruments, and photogrammetrist should be employed for each survey, if possible. The aircraft should be capable of flying slowly enough at low altitudes to allow for acquisition of high-resolution, small-scale photos without image motion blur or excessive geometric distortion. The pilot and photographer should be experienced in acquisition of low-altitude, high-resolution aerial photographs.

Step 2: Ground control survey. The ground control survey provides the reference control points needed to set up the stereoscopic photogrammetric models from which measurements are made. At least five evenly distributed control points (i.e., known x, y, and z coordinates) are required in each stereo photo pair to remove the effects of aircraft tilt, roll, and yaw (motion about the vertical axis) and earth curvature from the stereo photogrammetric models. In addition to the control points, large, distinctive targets should be painted on approximately 15 percent of the visible armor units to act as reference points. Reference points assist in identifying individual armor units for repeated measurements. The ground control survey should be carefully conducted to minimize random error.

Step 3: Aerial photograph flight. Considerations for an aerial photograph flight include tide level, weather, visibility, and time of day. In order to maximize armor unit or quarrystone exposure and minimize shadows, use tidal charts to find days when low tide and high sun angle (between 1100 and 1300 hours) occur simultaneously. In winter months, low sun angles produce

long shadows, even at noon, making acquisition of usable photography difficult. This is especially true for high northern latitudes where the sun does not get beyond 30 degrees above the horizon in November, December, and January. High visibility and calm weather are also important factors for a successful aerial photograph flight.

When the airplane, with its camera mounted for vertical mapping (i.e., with its optical axis perpendicular to the ground), is at a specified altitude directly over the project site, standard 60 percent forward lap photographs should be taken.

Step 4: Stereo photogrammetric compilation. If the compilation is accomplished by contract, a reputable photogrammetric firm with state-of-the-art equipment and experienced stereocompilers/photogrammetrists should be used. Using the control points, the stereo photogrammetric equipment will provide a stereo model (map) that is a true three-dimensional representation of the study area, free of geometric distortions. Extremely accurate measurements can be made on a stereo model to precisely position each armor unit with respect to the control points at the time the photos were taken. After subsequent surveys, the photogrammetric compilations can be compared to reveal any horizontal or vertical movement of the armor units to within ±0.3 ft.

COST: The cost of a typical control survey, flight, and photogrammetric compilation will vary considerably with the size of the surveyed area, the number of measurements required, and the location. A survey conducted for the Philadelphia District having an area of 2400 linear ft of jetty was accomplished for about $3200. This price included (1) aerial photography obtained at a scale of 1 in.:100 ft and (2) measurements of the positions of approximately 200 armor units. Subsequent surveys would cost less ($2200±) because it is not necessary to repeat the ground control survey. In contrast, a conventional survey would have cost about $1500, but only a random sample of armor units would have been surveyed since it is not practical to survey all units. Photogrammetry provides a permanent record of all visible armor units with great precision.

CONCLUSION: The primary concerns when monitoring movement of armor units or stones on a coastal structure are accuracy, repeatability, and economy of a

given measurement technique. Photogrammetry is more expensive than conventional survey techniques, but it may be the best method to obtain a complete survey and the degree of accuracy needed.

ADDITIONAL INFORMATION: Guidance on remote sensing techniques and aerial photographic mission planning is provided in Engineer Pamphlet 70-1-1, "Remote Sensing Applications Guide," available through the U. S. Government Printing Office, Washington, D.C. 20402, or the remote sensing coordinator in your District or Division office. For further information contact Mary Cialone, CERC Coastal Processes Branch, at (601) 634-2819 (FTS 542-2819), or the American Society of Photogrammetry at (703) 534-6617.

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